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# Proposed Addition of a Shower Max Detector to the STAR Zero Degree Calorimeters


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## I. EXECUTIVE SUMMARY


We propose the addition of a Shower Maximum Detector (one plane of 7 vertical slats and another of 8 horizontal slats) to the STAR Zero Degree Calorimeters, closely resembling the ZDC-SMD already used by PHENIX in RHIC run III. The SMD would add significant capability to STAR in four areas of physics: anisotropic flow, strangelet searching, ultra-peripheral collisions, and spin physics. The modest funding needed to implement this upgrade has been identified, and an ample manpower effort is available to complete the installation in time for RHIC run IV.


## II. PHYSICS MOTIVATION

The STAR ZDCs in their current form provide a signal that is correlated with the number of neutrons produced near beam rapidity. An upgrade that provides some information about the event-by-event pattern of transverse momentum among these neutrons opens up enhanced physics capabilities. In the subsections below, we discuss four areas of STAR physics where this new information promises to be of significant value.

### A. Flow

Besides the opportunity to study directed flow of nucleons in the nuclear fragmentation region, a new rapidity region for STAR, the adddition of the SMD will provide new information on the reaction plane, and can enhance the full range of anisotropic flow studies in the central TPC and the FTPCs.

The main advantages of using the reaction plane from the ZDC-SMD compared to the techniques currently used are:

- New knowledge concerning the *direction of the impact parameter vector*, since the reaction plane will be determined from the first harmonic flow. Besides other benefits mentioned below, this will make possible some measurements that are totally excluded at present, like HBT measurements with respect to the first order reaction plane (to measure the source tilt with respect to the beam axis).
- *Minimal, if any, non-flow effects.* Non-flow azimuthal correlations originate mostly from various kinds of cluster decays. These decays span a rapidity region of at most a few units. The ZDC, located in the projectile fragmentation region, is at least 6 units away from midrapidity.
- *Minimal, if any, effects from flow fluctuations.* The possibly large effects of flow fluctuations in present measurements are due to the fact that, for example, elliptic flow is measured with respect to the reaction plane determined from the same second harmonic flow, and in the same pseudorapidity region. Measurements to date of the n$^{th}$ harmonic signal $v_n$ have been of the form $\langle v_n^k \rangle^{1/k}$ rather than of the desired quantity $\langle v_n \rangle$ averaged over a certain set of events, and event-by-event fluctuations can cause these two observables to differ. The use of the reaction plane determined from the directed flow, and furthermore, from directed flow of spectator neutrons (as opposed to produced particles) would drastically suppress the correlations in fluctuations.

In the present STAR configuation, only the FTPCs provide information on the directed flow ($v_1$). Unfortunately, the directed flow among charged particles at FTPC pseudorapidities is very small, and $v_1(\eta)$ possibly changes sign within the region covered by the FTPCs. Both of these factors result in the FTPCs not being suitable to substitute in the role of the ZDC-SMD detector as explained above.

It is not required that the reaction plane resolution from the ZDC-SMD be as good as the 2nd-order reaction plane resolution obtained from the main TPC. In a typical analysis that is limited by systematic uncertainties rather than statistics, a decrease in the reaction plane resolution may not adversely affect the result. The reaction plane resolution that the ZDC-SMD will provide depends on the magnitude of $v_1$ among spectator neutrons, which has not yet been measured at RHIC. The best available indications suggest that spectator $v_1$ will be quite large. WA98 has measured a 20% $v_1$ signal among spectators at the SPS and $\langle p_x \rangle \approx 25$ MeV [1]. STAR measurements of $v_1$ among charged particles at FTPC pseudorapidities are remarkably close to the $v_1$ for pions in NA49 at the same pseudorapidity relative to the beam [2]. This observation is consistent with "limiting fragmentation" [3] and is supportive of the hypothesis that $v_1$ among spectators is independent of beam energy between SPS and RHIC. In fact, a much weaker adherence to limiting fragmentation than what has actually been observed would still be supportive of our assumption of a $\sim 20\%$ $v_1$ among spectators at RHIC.

### B. Strange Quark Matter

Strange quark matter is matter with about equal numbers of u, d and s quarks, existing in one QCD bag. It has been predicted to be metastable or stable [4]. It can be as small as the A=2 H-Dibaryon, or as large as a strange star with $A = 10^{57}$. Strange quark matter has many fascinating properties, and its existence would have major impacts on physics, astrophysics, cosmology, and possibly on technology as well [4]. Strange Quark Matter has been searched for among pulsars, stars and cosmic rays, as well as in the earth soil, and in heavy ion collisions. An extensive review of experimental results is provided in Ref. [5]. In heavy ion collisions, there have been several experiments dedicated to strangelet search: E864 and E896 at the AGS, and NA52 at the CERN/SPS. Further strangelet searches has been proposed to be carried out by AMS, ALICE and CMS. We propose to search for strangelets with $10 \lesssim \mathrm{mass} \lesssim 100$ in STAR. The basic idea is to detect the large energy deposition in the ZDC in central AuAu collisions. Central AuAu collisions provide violent compression of the nucleus and large numbers of baryons at forward rapidity, and is ideal for strangelet searching. Since the DX magnets sweep away the beam particles and other charged particles, ZDCs are only sensitive to neutral particles or matter with abnormally large mass-to-charge ratio.

### C. Ultra-peripheral Collisions

Adding an SMD to the STAR ZDCs would qualitatively expand the STAR UPC program, by allowing the study of photoproduction with polarized photons. The SMDs could be used to tag photon polarization, in a similar manner to how ZDC neutrons are used to tag the impact parameter vector. The neutron tagged samples have different impact parameter distributions from untagged events.

Position sensitive ZDCs are sensitive to the direction of the impact parameter vector. Most UPC single neutron tags come from giant dipole resonances (GDRs). GDRs decay in a simple dipole transition. In the transverse plane, the angle $\theta$ between the neutron $p_T$ and the photon polarization is distributed as $\cos^2\theta$. The photon polarization is parallel to the electric field vector. In a photonuclear interaction, the electric field parallels **b**. The neutron $p_T$ thus tags the direction of **b** [6]. Any additional photons in the reaction will also be polarized along **b**. When the ZDC is used to measure a neutron $pT$, it provides information about the polarization of other photons that participate in the reaction, tagging the photon polarization. The linearly polarized tagged beam can be used to study a variety of photonuclear interactions. Here, we mention 3 possible studies:
(1) Mutual GDR Excitation. Single neutrons are observed in each ZDC. The two neutron $p_T$ vectors should have an angular correlation:

$$C(\Delta\phi) = 1 + \tfrac{1}{2}\cos 2\Delta\phi$$

where $\Delta\phi$ is the angle between the two neutrons. For more complicated events, one could use mutual GDR as a double-tag, for even better determination of the photon polarization.
(2) Polarized $\rho^0$ Photoproduction. In $\rho^0$ decay, the $\pi^+$ and $\pi^-$ directions follow the photon polarization. In the simplest models, the plane formed by the $\pi^+$ and $\pi^-$ directions follows a $\cos^2\theta$ distribution with respect to the photon polarization. This has been studied with low energy photons, with very limited precision. STAR could look for violations from this simple diffractive prediction.

Less is known about heavier mesons; polarized $J/\psi$ photoproduction has not yet been studied experimentally. It may be sensitive to the polarized gluon content of nuclei. Inelastic $J/\psi$ photoproduction is of interest as a test of quarkonium production models [7].

(3) The polarization will be useful for further studies of wave function collapse. There should be no *a priori* knowledge of the direction of **b**, so in a mutual GDR excitation, the two excited nuclei form an entangled system of spin 1 particles; the neutrons from the decay act as spin analyzers. This system might be useful for tests related to Bell's inequality.

More speculatively, we could study polarized photoproduction of open charm.

### D. Spin Physics

The first collisions of transverse polarized protons at $\sqrt{s} = 200\,\mathrm{GeV}$ at RHIC from December 2001 until January 2002 (RUN2) at BNL is the beginning of a multi-year experimental program which aims to address a variety of topics related to the nature of the proton spin such as:
1. spin structure of the proton (gluon contribution of the proton spin, flavor decomposition of the quark and anti-quark polarization and transversity distributions of the proton),
2. spin dependence of fundamental interactions,
3. spin dependence of fragmentation and
4. spin dependence of elastic polarized proton collisions.
A recent review and status of the RHIC spin program can be found in Ref. [8].

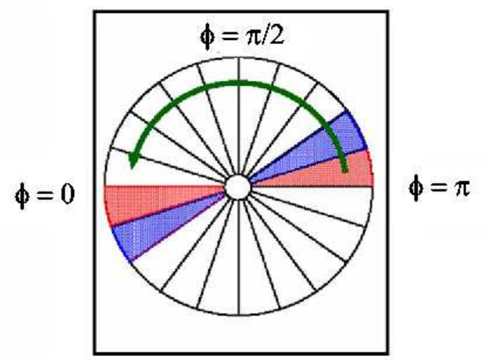


FIG. 1: Sketch of azimuthal angle regions of the PHENIX ZDC-SMD analysis of forward neutron production in polarized pp collisions.

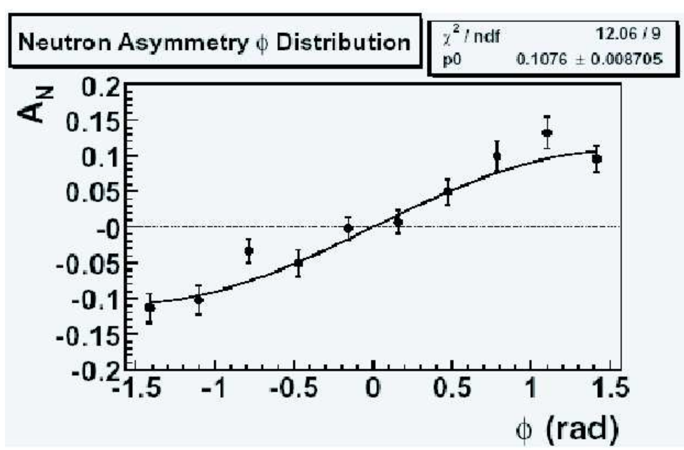


FIG. 2: Preliminary result of the measured neutron asymmetry as a function of the reconstructed azimuthal angle $\phi$ by the Local Polarimetry (PHENIX) collaboration using a Lead-Tungstate ($PbWO_4$) crystal electromagnetic calorimeter.

The first collisions of longitudinal polarized protons at $\sqrt{s} = 200\,\mathrm{GeV}$ have been achieved during RHIC run III in May 2003 with the successful commissioning of the STAR and PHENIX spin rotator magnets to allow for the precession from transverse to longitudinal polarization.

A focus of the first polarized proton run (RUN2) was the measurement of a transverse single-spin asymmetry, $A_N$. Non-zero values for $A_N$ have been observed at the FNAL E704 [9] experiment for $\vec{p} + p \rightarrow \pi + X$ at $\sqrt{s} = 20\,\mathrm{GeV}$ and $0.5 < p_T < 2.0\,\mathrm{GeV}$. Theoretical models that explain the E704 data also predict non-zero values for $A_N$ for pion production at RHIC. Qiu and Sterman [10] attribute the measured asymmetry to a higher-twist pQCD effect. The group of Anselmino and Leader performed a global analysis of semi-inclusive DIS data from HERMES [11] and E704 data. This approach involves transverse $k_\perp$ effects in the quark distribution functions ('Sivers effect') [12] as well as in the fragmentation functions ('Collins effect') [13] as possible explanations for the measured asymmetries. Besides the theoretical interest in measuring $A_N$, it serves as a potential candidate to monitor the RHIC beam polarization at the experiment ('local polarimeter'). The STAR collaboration has measured during the first polarized proton run (run II) the transverse single-spin asymmetry, $A_N$, for forward $\pi^0$ production at $x_F \simeq 0.2 - 0.6$ and $p_T \simeq 1 - 3\,\mathrm{GeV}$ [14]. $A_N$ is extracted from :

$$\epsilon = \cos\phi \; P A_N = \frac{N^{\uparrow} - R \cdot N^{\downarrow}}{N^{\uparrow} + R \cdot N^{\downarrow}} \tag{1}$$

which requires three independent measurements:
1. the spin-dependent yields ($N^{\uparrow(\downarrow)}$) of forward $\pi^0$ production,
2. the relative luminosity $R = L^{\uparrow}/L^{\downarrow}$ and
3. the actual beam polarization $P$.
The azimuthal angle $\phi$ is the angle between the polarization vector and normal vector to the production plane. $\epsilon$ is usually referred to as the raw asymmetry.

The actual raw asymmetry can be also reconstructed using a detector system which allows to provide sensitivity to the characteristic $\phi$ dependence. This method does not rely on knowing the relative luminosity which is restricted to transverse polarized beams. This scheme is sketched for the PHENIX ZDC-SMD arrangement in Figure 1. A Left/Right and Top/Bottom detector arrangement has been in fact realized by the upgraded STAR FPD detector system [15]. The STAR Beam-Beam counter with its complete $\phi$ coverage allows as well the reconstruction of the transverse asymmetry from its $\phi$ dependence [16]. The STAR Beam-Beam counter has been used in run III to tune the STAR spin rotator magnets [17].

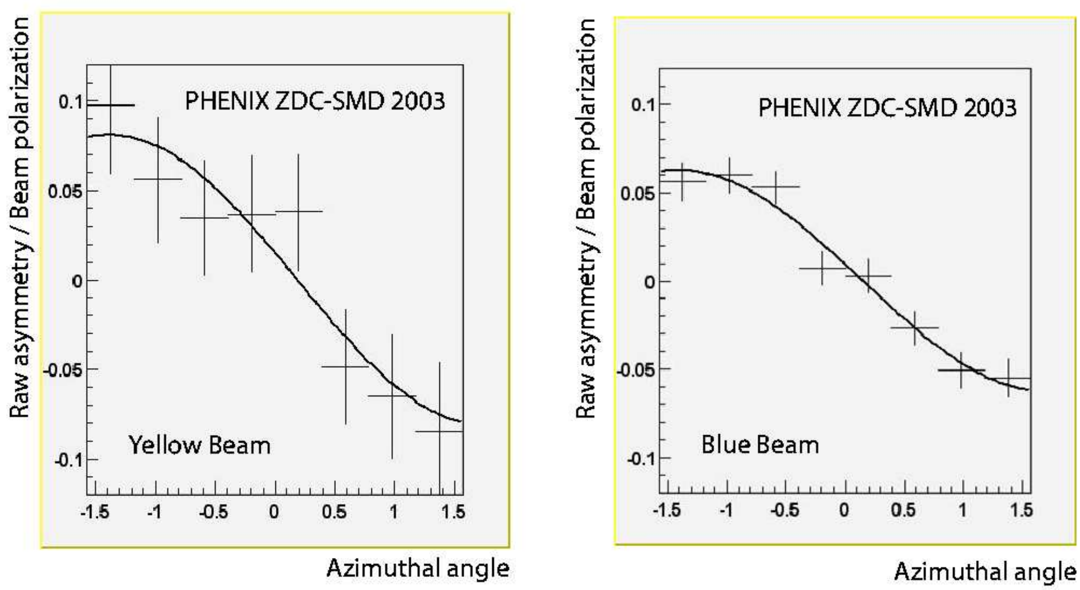


FIG. 3: PHENIX transverse raw asymmetries divided by the respective beam polarization for forward neutron production for Yellow (left) and Blue (right) spin sorting using the PHENIX ZDC-SMD detector system as a function of the reconstructed azimuthal angle in the range of $-\pi/2$ to $\pi/2$, ignoring sign conventions in $A_N$.

The Local Polarimetry (PHENIX) collaboration installed as part of the PHENIX 'local polarimeter' development for neutral particle production a detector system located 1800 cm upstream and downstream of the RHIC IP12 collision point [18].

An electromagnetic calorimeter (EM-Cal) which consists of sixty ($5 \times 12$ array) Lead-Tungstate ($PbWO_4$) crystals ($2.0 \times 2.0 \times 20.0\,\mathrm{cm}^3$) was installed on one side of the RHIC IP12 interaction region facing the RHIC 'blue beam'. The length of this $5 \times 12$ array corresponds to about one interaction length. This crystal array provides a means of position reconstruction. Sets of scintillation counters before and after the Lead-Tungstate array were used to define trigger conditions for photon and neutron samples. Simulation studies yield a purity of $98\%$ and $89\%$ for photons and neutrons, respectively. The systematic uncertainty has been estimated to be about $16\%$. The hadron calorimeter (H-Cal) which is a sandwich tungsten/optical-fiber calorimeter is installed on the other side of the RHIC IP12 interaction region which faces the RHIC 'yellow beam'. Its total length of 23 cm corresponds to about two interaction lengths. A postshower counter which consists of five $PbWO_4$ crystals provides a horizontal position measurement. Both calorimeter modules have an angular coverage of approximately 3 mrad around zero degrees. A scintillator hodoscope has been setup around the RHIC IP12 interaction region to suppress beam-related background events. Figure 2 shows the measured transverse single-spin asymmetry for forward neutron production, $A_N$, as a function of the reconstructed azimuthal angle which shows the expected azimuthal dependence. A fit to this dependence allows extraction of the underlying transverse single-spin neutron asymmetry. $A_N$ is found to be $-0.112 \pm 0.007$ with $\chi^2/ndf = 1.7$. The average measured $A_N$ value for positive $x_F$ amounts to $-0.109 \pm 0.007$ and $-0.110 \pm 0.015$ for the EM-Cal and H-Cal polarimeter, respectively. Both results agree within statistical uncertainties.

The underlying mechanism for non-zero transverse-single spin asymmetries for forward neutron production has not been understood. It will likely require a forward hadronic calorimeter system with larger acceptance to understand the origin of the measured forward neutron asymmetries in transverse polarized pp collisions.

The IP12 measurements resulted in the proposal to upgrade the then-existing ZDC system around the PHENIX IR region by a shower-maximum detector, and this upgraded system was used as a PHENIX local polarimeter system. Figure 3 shows the PHENIX transverse raw asymmetries divided by the respective beam polarization for foward neutron production for Yellow (left) and Blue (right) spin sorting using the PHENIX ZDC-SMD detector system as a function of the reconstructed azimuthal angle in the range of $-\pi/2$ to $\pi/2$, reflecting the characteristic azimuthal dependence [19]. Sign conventions in $A_N$ have not been taken into account. These results have been used to tune the PHENIX spin rotator magnets during RHIC run III [20].

This clearly demonstrates the usefulness of such an upgraded detector system as an additional local polarimeter system besides the STAR FPD and STAR BBC detector system. It also has the potential to provide a means of relative luminosity measurement which is crucial for any asymmetry measurement in longitudinal polarized proton collisions, e.g., the measurement of $A_{LL}$, which is the principal measurement to access the gluon polarization.

## III. SIMULATIONS

### A. Flow

The simulations in this section mainly address the question of how well resolved will be the expected neutron $v_1$ signal over a range of centralities. Also, we briefly address the issue of the smallest $v_1$ that could be resolved among the neutrons.

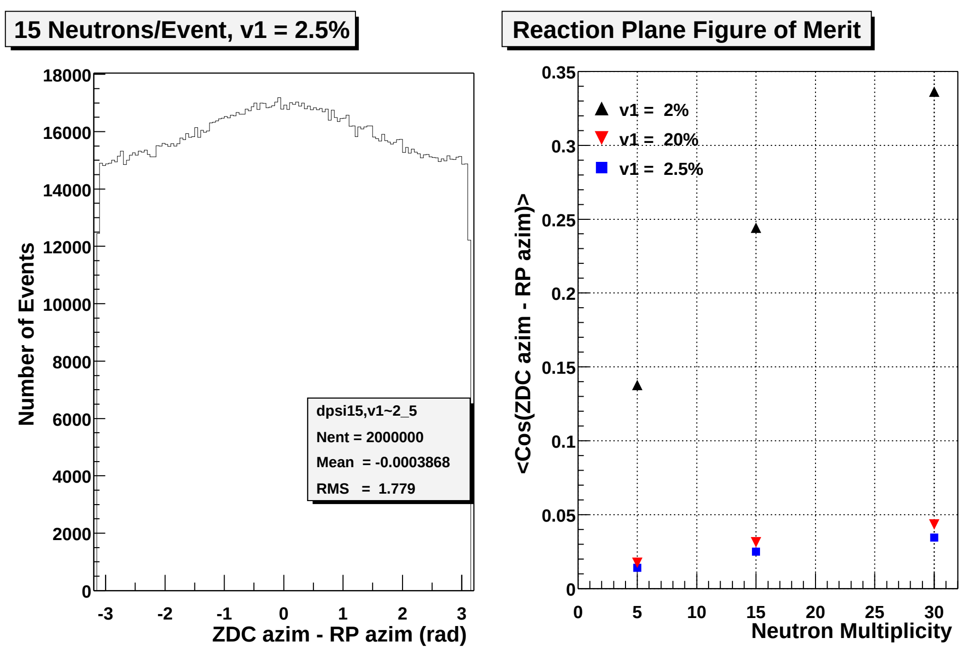


FIG. 4: Flow simulation.

The simulations are based on a number of assumptions or approximations:

- In each event, up to 30 neutrons are incident upon each ZDC. We consider three cases: 5, 15 and 30 neutrons.
- Spectator neutrons are generated with a random $p_T$ distribution according to Fermi momentum. Each event is assigned a random reaction plane azimuth, and a $v_1$ correlation is then imposed.
- We assume $v_1$ = 20% as the most likely value to be found among spectators at RHIC (see above). In order to probe the response to a much smaller $v_1$ signal, we also investigate $v_1$ = 2% and 2.5%. These values allow us to verify sensitivity to small signals.
- We assume that the shower produced by each neutron deposits light in more than one slat in each of the two layers according to a Gaussian profile in the transverse plane. We assume a standard deviation of 1.8 cm in each of x and y. This parameter comes from work oriented to this project using a GEANT-based simulation code first developed when the ZDCs were being designed [21]. This GEANT-based ZDC code has since been verified as being in excellent agreement with real data.
- For each simulated event, we sum the shower signals for the individual neutrons in each plane of slats. We assume a linear response in all parts of the signal chain. The mean position along each axis defines a centroid point in the transverse plane for each event.
- The azimuth of the centroid relative to the point that corresponds to $p_T$ = 0 is the estimated reaction plane azimuth. Computing this quantity is not necessarily the most useful way to extract physics in practice, but it is an intuitive observable and is well-suited for illustrating the expected performance of the device.

The left-hand panel of Fig. 4 illustrates a typical distribution of the difference between the input reaction plane azimuth and the azimuth reconstructed as per the simulation above. The relative strength of the signal, i.e., the extent to which the distribution is peaked at zero angular difference, can be characterized by the mean cosine of the angular difference. The right-hand panel summarizes this correlation strength (essentially a figure of merit for how well the azimuth of the reaction plane is resolved) for all 9 cases studied — 3 different values for $v_1$ and 3 different spectator neutron multiplicities. Even in the case of the smallest $v_1$ and lowest neutron multiplicities, the plotted figure of merit $\langle\cos(\Phi_{\rm ZDC} - \Phi_{\rm RP})\rangle$ would still be adequate to extract useful physics. For the reasons discussed under flow motivation above, the black triangles correspond to what we expect to observe in the ZDC-SMD.

The final limit on the smallest $v_1$ that could be resolved would be set by subtle systematic effects that cannot readily be simulated. We consider this to be a moot issue, because the expected signal based on experimental indications far exceeds the threshold $v_1$ sensitivity of the ZDC-SMD.

### B. Strangelets

In order to get an idea of the sensitivity of the SMD's response to strangelets, we have simulated two events with equal amount of energy deposition in the ZDC. One event consists of 35 neutrons with a typical distribution of $p_T$, and the other event contains only a single strangelet with a mass 35 times that of a neutron. The hits distribution along a transverse axis in the normal event is shown in the left panel of Figure 5.

In the plot, the hits deposition in one layer of the ZDC (out of 260 in total) is projected to the Y axis (both X and Y axes are perpendicular to the beam direction). The layer is chosen to be at a position of about one-third of the total depth of the ZDC, where the SMD will be installed. Due to the normal $p_T$ distribution among spectator neutrons, the hits are dispersed along the Y axis. The same simulation repeated for a strangelet shows a prominent peak and less dispersion (see the right panel of Figure 5). These two plots demonstrate that we can distinguish a strangelet from a normal event if the ZDC-SMD is implemented.

## IV. HARDWARE CONFIGURATION

The ZDC-SMDs will be placed between the first and second modules of the ZDCs (see Fig. 6). The SMD is an 8 channel by 7 channel hodoscope that sits directly on the face of the 2nd ZDC module (see Fig. 8). The hodoscope is made with strips of scintillating plastic that are laid out in an X-Y pattern, with 21 strips having their long axes vertical and 32 strips having their long axes horizontal. The cross section of each strip is approximately an equilateral triangle with an apex-to-base height of 7 mm; see Fig. 7. A hole running axially along the center of each triangle allows the insertion of a 0.83 mm WLS fiber which is used to collect and transport the scintillation light. Individual triangular strips are wrapped with 50 $\mu$m aluminized mylar to optically isolate them from their neighbors. The wrapped scintillator strips are then epoxied between two G-10 sheets to form a plane. Each slat aligned in the vertical direction consists of three strips, and the corresponding three fibers are joined to make one channel, and routed to the face of a 16-channel segmented cathode phototube conveniently located in a chassis above the

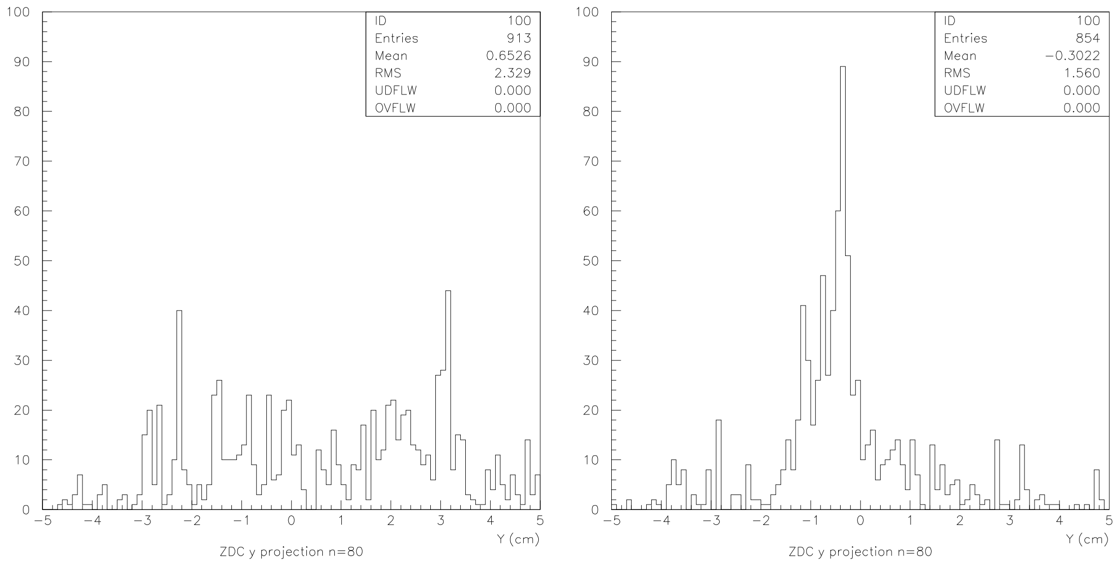


FIG. 5: Simulation of a normal event (left) and a strangelet event (right).

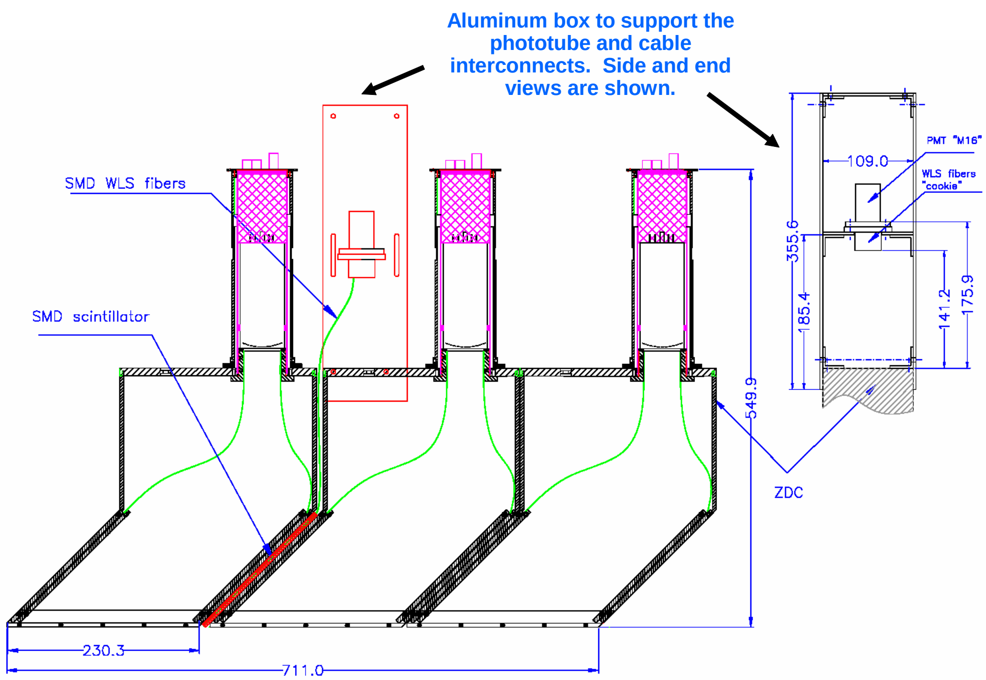


FIG. 6: The SMD fits between the existing ZDC modules.

SMD. The slats aligned in the horizontal direction are each made up of four strips and their fibers. The overall dimensions of the hodoscope are approximately 2 cm $\times$ 11 cm $\times$ 18 cm (see Fig. 9).

The chassis to support the phototube is a simple Aluminum structure that is designed to be sturdy and to bear the load of the phototube and the 16 cables hanging off the tube. It also supports the weight of the HV and BNC cables that go to the electronics racks on the STAR detector. The design of the chassis, hodoscope, and phototubes are identical to the design that was used in PHENIX by Sebastian White and his collaborators during run III.

The phototube is a 16-channel multi-anode PMT with a conventional resistive base (Hamamatsu H6568-10 [22]). The tube

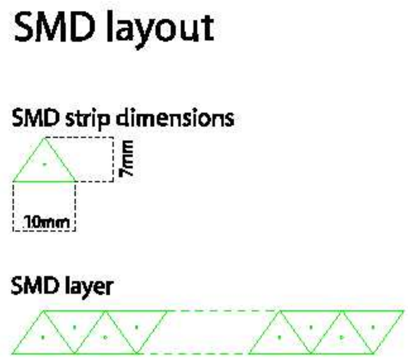


FIG. 7: The SMD planes are built-up from scintillator strips with triangular cross section.

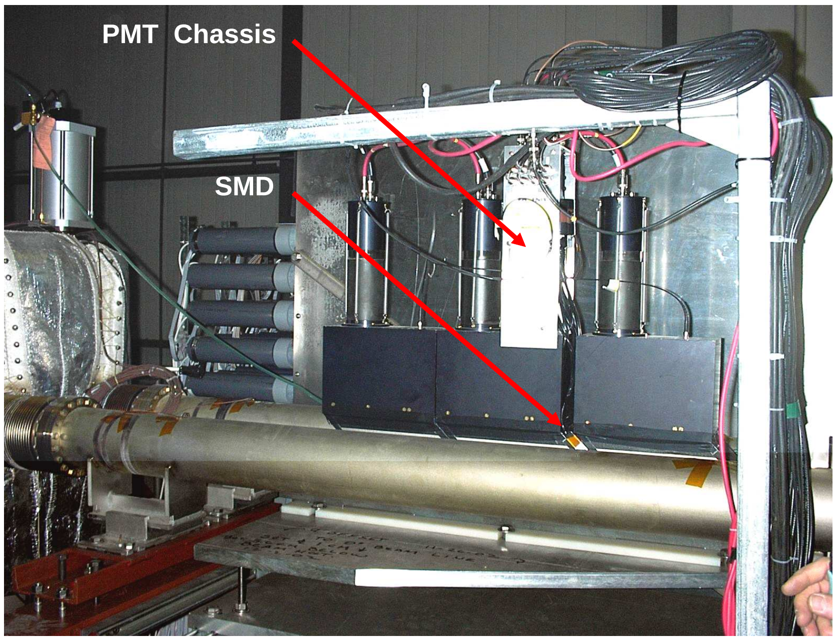


FIG. 8: An SMD module shown installed at PHENIX.

requires DC at $-0.75$ kV HV and it uses sixteen 50 ohm BNC cables for output. The sixteenth channel is a "sum" output. The electronics for the readout of the phototube already exist and will be taken from spares for the STAR CTB.

The forward scintillation counter monitors for possible beam leakage and backgrounds in the tunnel, it can also serve as a charged particle veto during pp runs (see Fig. 10). It is placed 9 cm in front of the first module of the ZDC. It consists of a single plastic scintillator with dimensions 10 cm (horizontal) $\times$ 13 cm (vertical) $\times$ 1/4 inch (thickness), a light guide, and a conventional PMT (Hamamatsu 2490-05) with a resistive base.

## V. IMPACT ON STAR

The impact on STAR is expected to be minimal. The primary change to the existing apparatus is that the 2nd and 3rd ZDC modules will be moved away from STAR by about 2 cm in order to create a gap between modules 1 and 2. All other ZDC locations and the alignment with the beam will stay the same.

The gap will be used for the installation of the SMD. The SMD itself is approximately 1.5 cm of plastic and 2 mm of G-10 tilted on a 45 degree angle. This puts about 3 g/cm$^2$ of material in the path of neutrons coming from the interaction point. This amount of material is negligible compared to the $> 270$ g/cm$^2$ of Tungsten and plastic in each ZDC module which comes before and after the SMD.

Perhaps more important is the fact that ZDC modules 2 and 3 have moved away from module 1. This means they will be

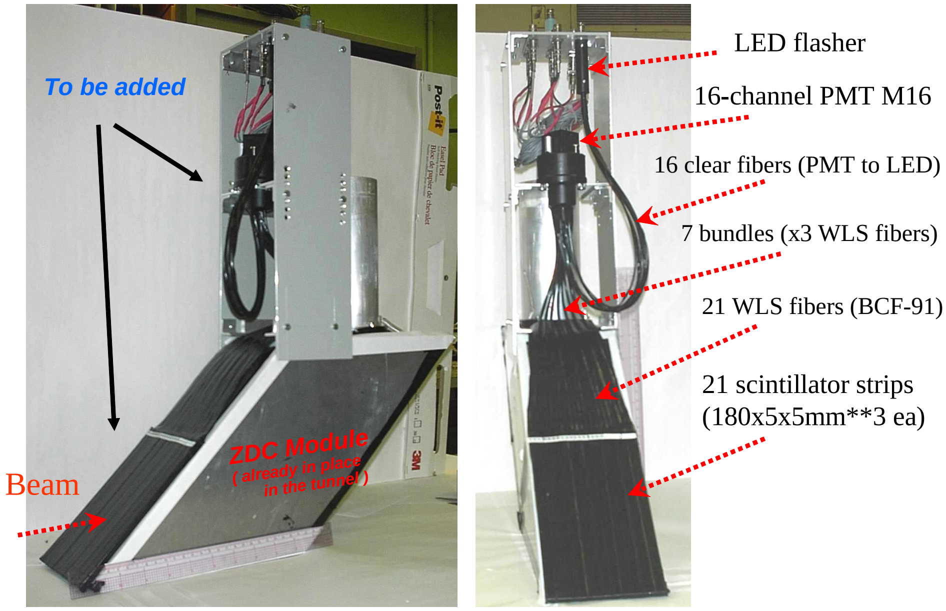


FIG. 9: The SMD and PMT chassis mounted on a dummy ZDC module. Note that the scintillator strips in the horizontal direction are not shown.

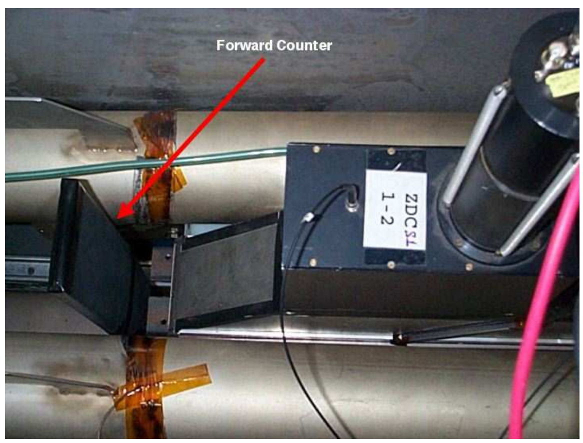


FIG. 10: Forward Counter installed at PHENIX.

sampling the neutron induced showers at a slightly greater depth in the shower. We do not expect this change to be significant because the ZDCs are calibrated annually and the change in performance of the ZDCs is expected to be below the rms of the calibration error. Zhangbu Xu will coordinate the calibration of the ZDCs.

The responsibility to ensure correct installation of the SMD and to ensure that the normal ZDC trigger functions are not impacted by this project will be jointly assumed by Hank Crawford and Zhangbu Xu.

## VI. MANPOWER CONSIDERATIONS

Graduate student Gang Wang, who has carried out the flow simulations, has relocated to BNL and is available to devote 100% of his time to this project. Mikhail Kopytine, Aihong Tang, and Zhangbu Xu will devote whatever fraction of their effort is needed during review, installation and shakedown. Gang Wang will analyze the flow data, Aihong Tang will analyze the strangelet search, and members of the UPC and Spin PWGs yet to be identified will pursue the other physics directions. Bernd Surrow is contributing to this project during the review and implementation phase, and will ensure that STAR spin physics interests are understood and accomodated. Spencer Klein will ensure that STAR UPC physics interests are understood and accomodated. Jim Thomas will provide oversight as needed during review and installation of the detector.

Formally, the ZDC is part of the trigger subsystem, and Hank Crawford is the project leader for all trigger subsystems. Declan Keane and Zhangbu Xu will share direct responsibility for the SMD upgrade.

## VII. IMPLEMENTATION PLAN

The SMD implementation costs and timeline are outlined in the table below. The total project cost in terms of immediate dollar expenditures, not counting in-kind contributions from various STAR institutions, is approximately $4.8k. The source for these expenditures has been identified.

The most time-consuming installation step in the tunnel and hall has to do with cables and patch panels. This work is planned to be competed well before the close-up to begin tuning for run IV. The final implementation step will be the installation of the two slat planes between the first and second modules of each ZDC. We understand that when PHENIX carried out this operation last year, it was completed in three hours. Thus it is a step that could be postponed, as will probably be necessary, until after close-up.

| TASK | PERSON(S) | DATE | $k | BUDGET |
|---|---|---|---|---|
| **Documentation:** | | | | |
| Proposal completion | Authors, Reviewers | Nov | | |
| Prelim. safety review | Christie, Thomas | Done | | |
| Final safety review | Christie, Thomas | Nov | | |
| **Purchases/acquisitions:** | | | | |
| Scintillator | B. Surrow | Nov 15 | 0 | (EEMC left-overs) |
| Fibers | Surrow, Xu | Done | 0 | (EEMC left-overs) |
| Fiber mounting cookies | J. Thomas | Nov 17 | 0.5 | (from LBNL) |
| 2 MAPMTs | D. Keane | Done | 0 | (value 2.68, loaned by EEMC) |
| 2 PMTs for chg. veto | Z. Xu | Done | 0 | (ZDC spares) |
| Signal cable/connectors | A. Tang | Done | 3.6 | (from BNL) |
| SHV cable/connectors | D. Keane | Done | 0.7 | (from Kent SU) |
| Flexible cable conduit | A. Tang | Done | 0 | (from BNL) |
| Readout electronics | H. Crawford | Done | 0 | (STAR trigger spares) |
| HV supplies | H. Crawford | Done | 0 | (4 spare BBC channels) |
| **Fabrication/assembly:** | | | | |
| SMD Aluminum chassis | S. Voloshin | Done | 0 | (value 0.5, from Wayne SU) |
| ZDC-end patch panels | D. Padrazo | Nov 7 | 0 | (from BNL) |
| Platform patch panel | K. Asselta | Nov | 0 | (from BNL) |
| SMD optical | Xu, Surrow, + | late Nov | | |
| Chg. particle veto | Xu, Tang | Nov. | | |
| **Installation steps:** | | | | |
| Cabling | Xu, + | early Nov | | |
| SMD mech/optical | Crawford, Xu, + | early Dec | | |
| **Software:** | | | | |
| Slow Controls for HV | B. Waggoner | Nov 21 | | |
| Signal readout | J. Engelage | Done | | |

## VIII. ACKNOWLEDGMENTS

We are grateful to Sebastian White for extensive technical support, and to Maxim Potekhin for help with GEANT simulations. The authors acknowledge considerable assistance from Jim Thomas and from Bill Christie in preparation of this document and

in implementation work to date.

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